

Monitoring Requirements Coverage using Reconstructed Views

An Industrial Case Study

Marco Lormans,
M.Lormans@ewi.tudelft.nl / Marco.Lormans@LogicaCMG.com
www.st.ewi.tudelft.nl/~lormans

Joined work with:
Hans-Gerhard Gross and Arie van Deursen (Delft University of Technology),
Andre Stehouwer (LogicaCMG),
Rini van Solingen (LogicaCMG and Drenthe University)

SPIder 2007
Philips Medical Systems, Best, The Netherlands

12 February 2008

1

Agenda

- Introduction, Motivation and Background (By André Stehouwer, LogicaCMG)
- Background
 - Requirements Views
 - Approach for Reconstructing Views
- Research Questions
 - Views Questionnaire
 - ReqAnalyst Tool Suite
- Case Study at LogicaCMG
- Discussion of Results
- Concluding Remarks

Introduction by André Stehouwer

Project manager TMS project at LogicaCMG

12 February 2008

3

M.Lormans@ewi.tudelft.nl
SPI der 2007



Motivation

- Monitoring the progress (of requirements) in product development is difficult
- It requires accurate traceability data, which turns out to be very hard to obtain and maintain in practice
- Currently available tool support is insufficient
 - Input of links is a manual task
 - Links get lost during evolution

What are Requirements Views?

A “requirements view” on a system or development process offers a perspective on that system in which requirements are leading [Nuseibeh 1994].

For example, views related to

- *Testing*; showing the requirements that have been successfully tested
- *Design*; showing the requirements that resulted in a specific design decision
- *Coding*; showing the requirements that were actually implemented

Approach for reconstructing Requirements Views

1. Defining the Traceability Meta-Model
2. Identifying the Work Products
3. Preprocessing the Work Products
4. Reconstructing the Traceability Links
5. Selecting the Relevant Links
6. Generating Requirements Views

Research Questions

1. Which requirements views are most needed in practice?
2. How and to what extent these particular requirements views can be reverse engineered from existing work products?
3. Are these reconstructed views helpful in a real life software development process?

Research Questions

1. **Which requirements views are most needed in practice?**
2. How and to what extent these particular requirements views can be reverse engineered from existing work products?
3. Are these reconstructed views helpful in a real life software development process?

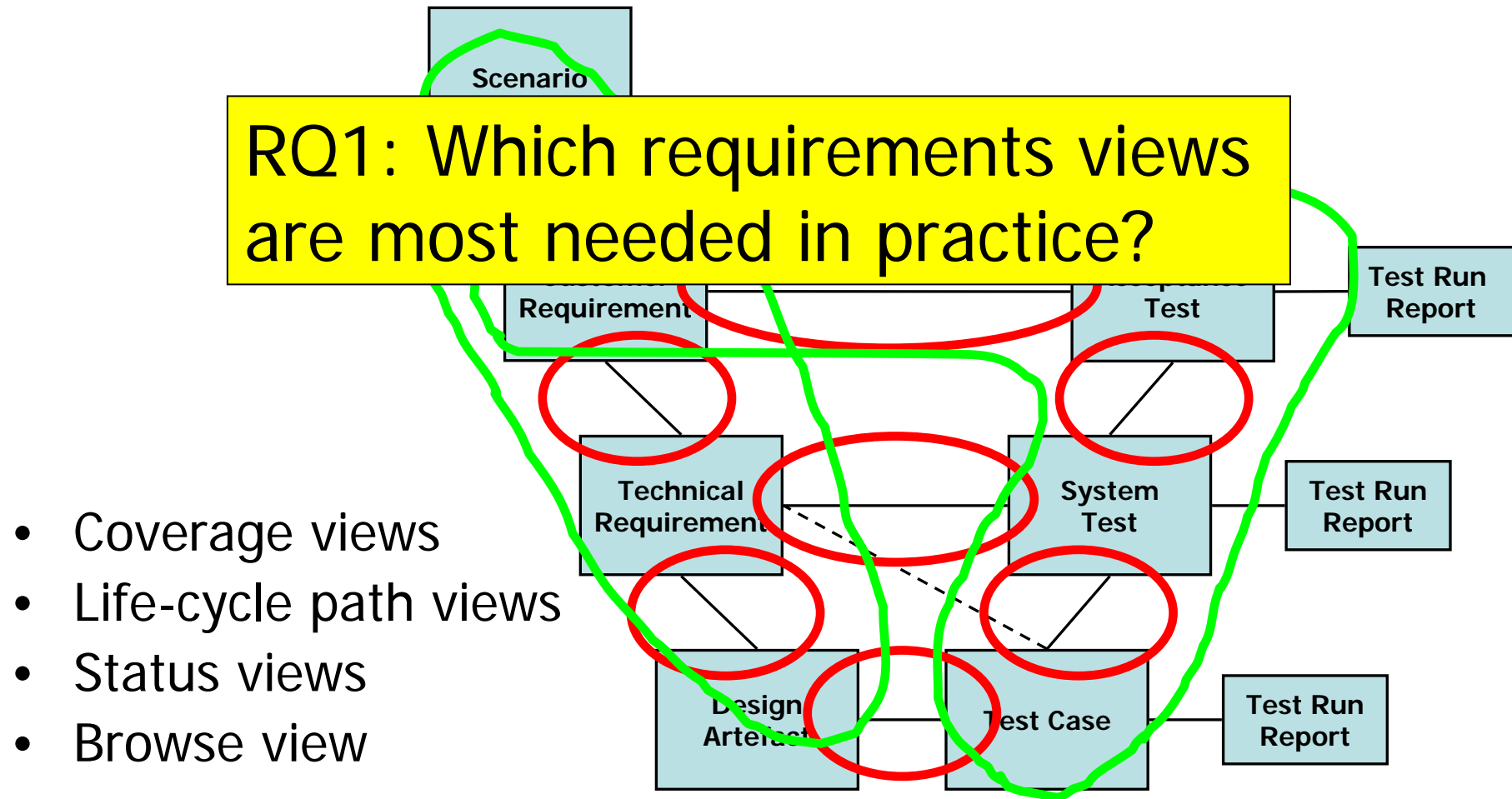
Views Questionnaire

Questions:	
1)	What is your role in the software development life-cycle?
2a)	What do you expect from a requirements view?
2b)	What information would you like to see in a requirements view? (Examples: coverage, functionality, status)
3a)	What do you think persons in the roles below expect from a requirements view? - Project Manager - Requirements Engineer - System Architect - Programmer - Test Engineer - Quality Manager - Other? (please also define the role)
3b)	What information do you think they would like to see? (Do not fill in your own role again)
4)	Do you think it is feasible to extract this information from the work products currently produced during development? (requirements specifications, design documents, etc.)

Which Requirements Views are Needed in Practice?

- Per requirement, their source, description, motivation, importance, history, status and dependencies to other work products
- Per set of requirements, a list of all requirements including the status of their implementation and verification (not tested, test passed, test failed)
- Per requirement, the complete path it undergoes during the life-cycle (Life-cycle paths)
 - The Requirements-Implementation path
 - The Requirements-Test path.
- For all the requirements the coverage in a certain work product

Requirements Views



Research Questions

1. Which requirements views are most needed in practice?
- 2. How and to what extent these particular requirements views can be reverse engineered from existing work products?**
3. Are these reconstructed views helpful in a real life software development process?

ReqAnalyst Tool Suite

- ReqAnalyst uses the Extract-Query-View approach
 - The tool can *extract* the relevant data from the provided documentation (work products and reference traceability matrices)
 - The tool can *reconstruct* traceability matrices from the extracted work products using Information Retrieval techniques
 - The tool can *generate* requirements views from the extracted work products and reconstructed traceability matrices

The ReqAnalyst Tool Suite

Menu:

For extracting the data:

Requirements

Test Categories

Extract Document Collection

Extract Term-by-Document Matrix

Extract Traceability Matrix

For reconstructing the traceability links:

Requirements

Test Categories

If you want all documents included in the analysis:

yes

k-rank subspace (1,100):

40

Constant threshold (eps) (-1,1):

0.3

Variable threshold (eps) (1,100):

30

Link Selection Strategy:

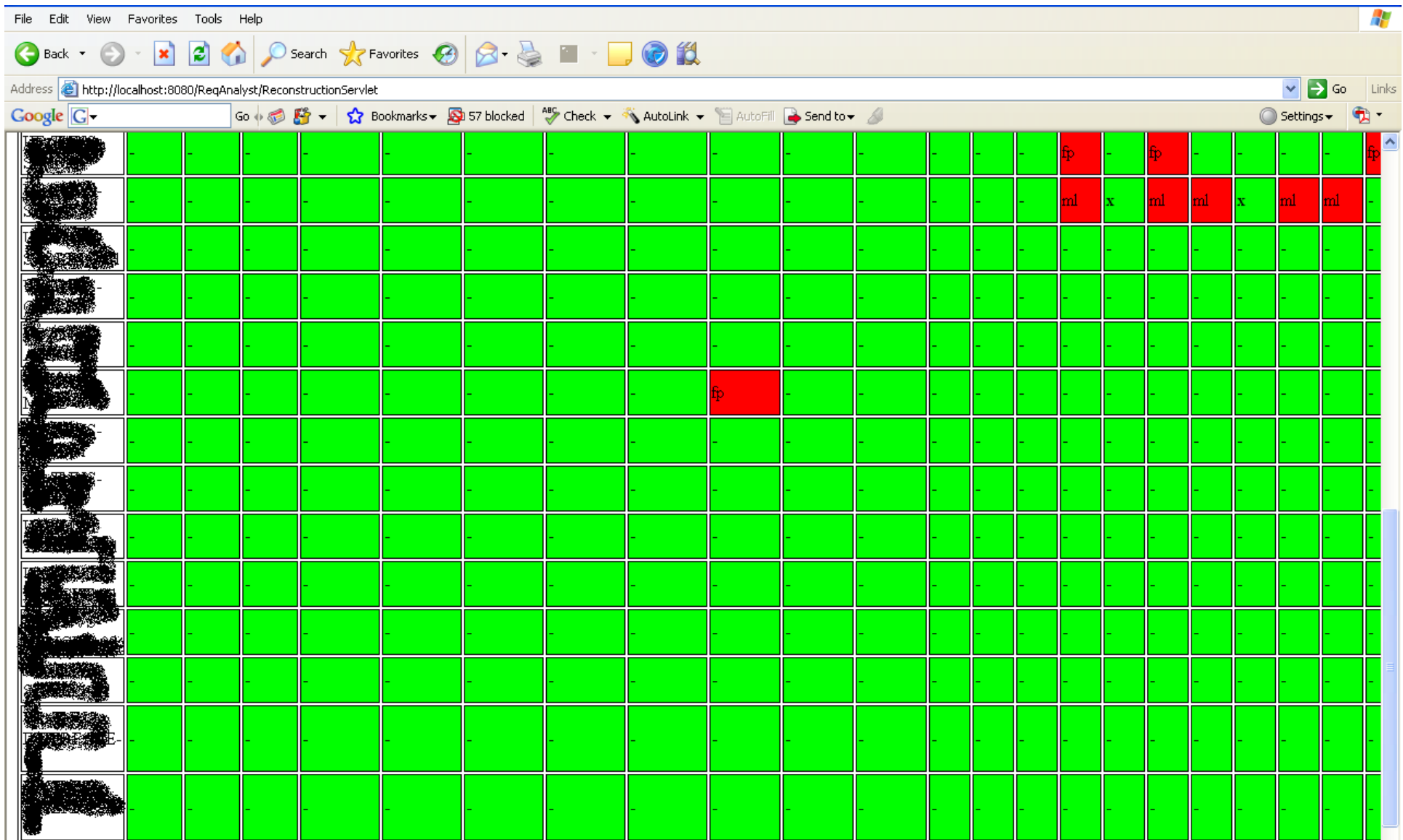
Two Dimensional Filter

Reconstruct Links

For a different project:

Choose different project

	UC1	UC2	UC3	UC4	UC5	UC6	UC7	UC8	UC9	GUI
TC1	x	-	-	-	-	-	-	fp	-	fp
TC2a	-	x	-	-	fp	-	-	-	-	-
TC2b	-	x	-	-	fp	-	-	-	-	-
TC2c	-	x	-	-	fp	-	-	-	-	-
TC3a	-	-	x	-	-	-	-	-	-	-
TC3b	-	-	x	-	-	-	-	-	-	-
TC4	-	-	-	x	-	fp	fp	-	fp	-
TC5a	-	-	-	-	ml	-	-	-	-	-
TC5b	-	-	-	-	x	-	-	-	-	-
TC5c	-	-	-	-	x	-	-	-	-	-
TC5d	-	-	-	-	x	-	-	-	-	-
TC6	-	fp	-	fp	-	x	fp	-	fp	-
TC7	fp	-	-	-	-	-	x	fp	-	fp
TC8	fp	-	-	-	-	-	fp	x	-	fp
TC9a	-	-	-	-	-	fp	fp	-	x	-
TC9b	-	-	-	-	-	fp	fp	-	x	-
TC10	fp	fp	fp	-	-	-	fp	fp	-	x



The recall for this reconstruction is: 0.58181818181818
The precision for this reconstruction is: 0.32989690721649484

There are 130.0 false positives and 46.0 missing links.
In total there are 3509.0 candidate links and there are 194.0 links retrieved.
64.0 of them are correctly retrieved.

There are 58.0 requirements not covered of the total set of 121.0 requirements.

The coverage of the requirements

The following requirements do

ATG-1

~~For every ATG, the following~~

ATG-10

~~For every ATG, the following~~

ATG-2

~~For every ATG, the following~~

ATG-4

~~For every ATG, the following~~

ATG-8

~~For every ATG, the following~~

ATG-9

~~For every ATG, the following~~

COMB-1

~~For every ATG, the following~~

RQ2: How and to what extent
these particular requirements
views can be reverse
engineered from existing work
products?

Research Questions

1. Which requirements views are most needed in practice?
2. How and to what extent these particular requirements views can be reverse engineered from existing work products?
3. **Are these reconstructed views helpful in a real life software development process?**

LogicaCMG Case Study

12 February 2008

19

M.Lormans@ewi.tudelft.nl
SPI der 2007



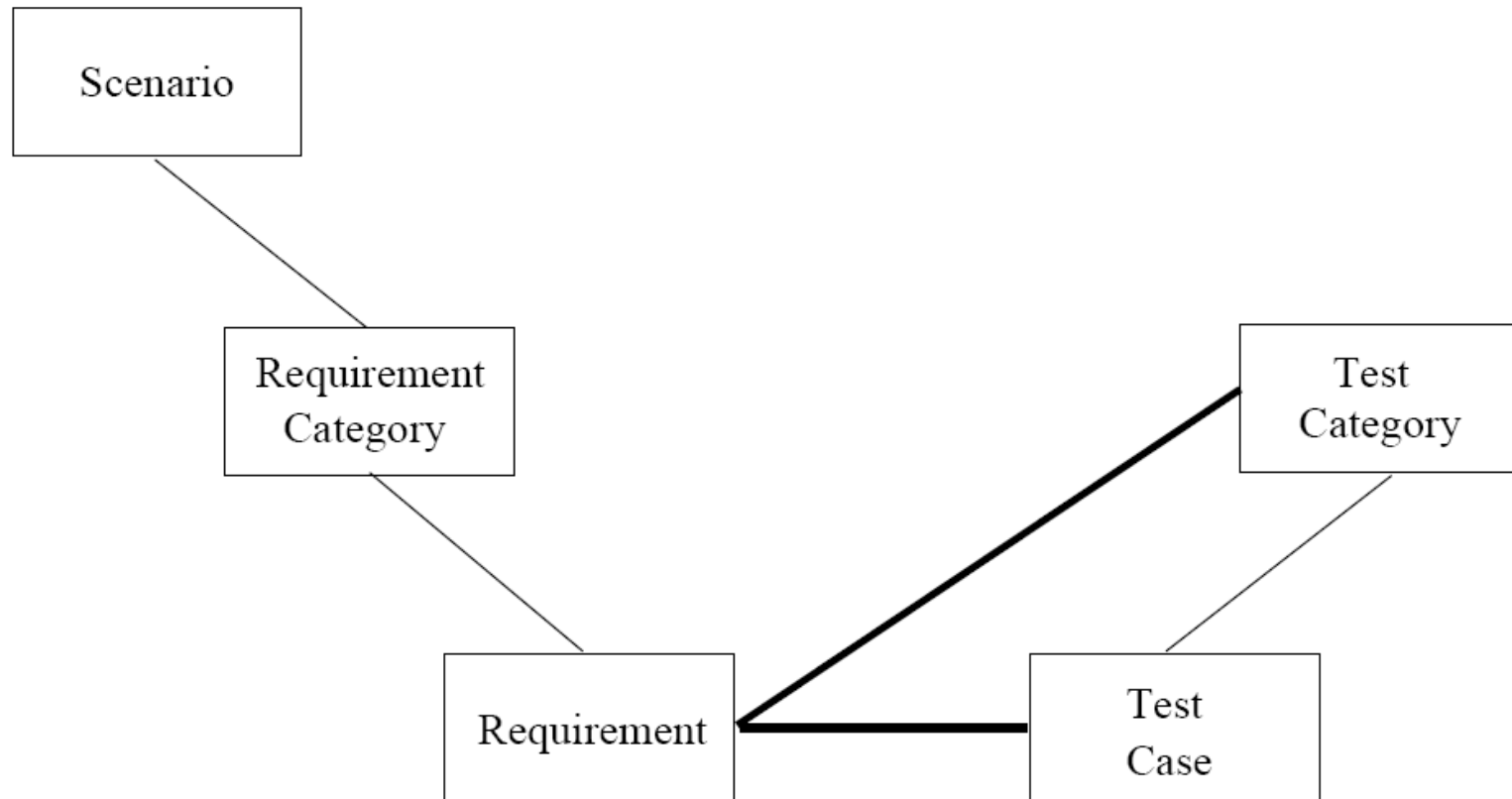
Case Context

- Traffic Monitoring System (TMS), which is an important part of a traffic control and logistics system
- Provided documents
 - System/ Subsystem Specification (SSS)
 - Software Test Description (STD)
 - Set of Test Cases ('tst'-files)
 - HTML representation of Test Cases generated by Doxygen
 - Traceability Matrix of Requirements to Test Cases
- We used *Latent Semantic Indexing* (LSI) for the reconstruction of the traceability Links

Main problems at LogicaCMG

1. *Unreliability*, as the consistency of the traceability links could not be guaranteed. It was hard to keep the links consistent during the evolution of the project
2. The *manual work* for synchronizing the updates from the client introduced errors, was time consuming and cost the project an unbalanced effort

Traceability Model



Case Statistics

Work product type	Number	Size in terms	Avg. terms per doc.
Requirements Categories	45	1168	183
Requirements	121	695	29
Test Categories	29	589	183
Test Cases	98	886	107

Link source	Link target	# Reference links	# Candidate links
Requirements Categories	Requirements	121	5445
Requirements Categories	Test Categories	31	1305
Requirements	Test Categories	110	3509
Requirements	Test Cases	297	11858
Test Categories	Test Cases	122	2842

Results of Requirements to Test Categories



Link Type: Requirements – Test Categories								
c	q	Reconstructed Links		Missing Links	Recall	Precision	Validation Percentage	Coverage Percentage
		Correct Positives	False Positives					
0.3	20%	51	29	59	0.46	0.64	2	43
0.3	40%	75	324	35	0.68	0.19	11	62
0.3	60%	82	722	28	0.75	0.10	23	68
0.3	80%	82	740	28	0.75	0.10	23	68
0.2	80%	95	1389	15	0.86	0.06	42	77
0.1	80%	107	2152	3	0.97	0.05	64	83

Results of Requirements to Test Cases



Link Type: Requirements – Test Cases								
c	q	Reconstructed Links		Missing Links	Recall	Precision	Validation Percentage	Coverage Percentage
		Correct Positives	False Positives					
0.3	20%	66	419	231	0.22	0.14	4	26
0.3	40%	141	2254	156	0.48	0.06	20	45
0.3	60%	186	3938	111	0.63	0.05	35	53
0.3	80%	186	3967	111	0.63	0.05	35	53
0.2	80%	223	6265	74	0.75	0.03	55	67
0.1	80%	260	8508	37	0.88	0.03	74	74
0.05	80%	265	8682	32	0.89	0.03	75	74
0.05	90%	276	10030	21	0.92	0.03	87	74

There are 58.0 requirements not covered of the total set of 121.0 requirements.
The coverage of the requirements in the testcategories is: 0.5206611570247934.

The following requirements do *not* have a link to the testcategories:

ATG-1

~~ATG-1: The system shall be able to handle a maximum of 1000 concurrent users. (ATG-1 is not linked to any testcategory)~~

ATG-10

~~ATG-10: The system shall be able to handle a maximum of 1000 concurrent users. (ATG-10 is not linked to any testcategory)~~

ATG-2

~~ATG-2: The system shall be able to handle a maximum of 1000 concurrent users. (ATG-2 is not linked to any testcategory)~~

ATG-4

~~ATG-4: The system shall be able to handle a maximum of 1000 concurrent users. (ATG-4 is not linked to any testcategory)~~

ATG-8

~~ATG-8: The system shall be able to handle a maximum of 1000 concurrent users. (ATG-8 is not linked to any testcategory)~~

Requirements Categories	Requirements	Test Categories	Test Cases
[REDACTED]	[REDACTED]-1 [REDACTED]-2 [REDACTED]-3	[REDACTED]-01	
[REDACTED]	[REDACTED] 1 [REDACTED] 2 [REDACTED] 3 [REDACTED] 4 [REDACTED] 5	[REDACTED]-01	
[REDACTED]	[REDACTED] 1 [REDACTED] 2 [REDACTED] 3	[REDACTED]-01	[REDACTED] [REDACTED]
[REDACTED]	[REDACTED] 1		[REDACTED]
	[REDACTED] 2		[REDACTED]
	[REDACTED] 3		[REDACTED]
	[REDACTED] 4		[REDACTED]
	[REDACTED] 5		[REDACTED]
	[REDACTED] 6		[REDACTED]
	[REDACTED] 7		[REDACTED]
	[REDACTED] 7B		[REDACTED]
	[REDACTED] 8		[REDACTED]
	[REDACTED] 9		[REDACTED]
	[REDACTED] 10		[REDACTED]
	[REDACTED] 11		[REDACTED]
	[REDACTED] 12	[REDACTED]-01	[REDACTED]
	[REDACTED] 13	[REDACTED]-02	[REDACTED]
	[REDACTED] 14	[REDACTED]-03	[REDACTED]
	[REDACTED] 15	[REDACTED]-04	[REDACTED]
	[REDACTED] 16	[REDACTED]-05	[REDACTED]
	[REDACTED] 17		[REDACTED]
	[REDACTED] 18		[REDACTED]
	[REDACTED] 19		[REDACTED]
	[REDACTED] 20		[REDACTED]
	[REDACTED] 21		[REDACTED]
	[REDACTED] 22		[REDACTED]
	[REDACTED] 23		[REDACTED]
	[REDACTED] 24		[REDACTED]
	[REDACTED] 25		[REDACTED]
	[REDACTED] 26		[REDACTED]
	[REDACTED] 27		[REDACTED]
	[REDACTED] 28		[REDACTED]
	[REDACTED] 29		[REDACTED]

12 Feb

27

Lessons Learned (1)

Quality of the Reconstructed Links

- The results for the various link types differ

Consistent Traceability Support

- We found small inconsistencies in SSS and traceability data maintain in MS-Excel
- ReqAnalyst can identify these kind of inconsistencies

Effort Reduction

- Is the 35% effort reduction reasonable in practice?
- Increments can take into account the validated reference traceability matrix reducing validation effort

Lessons Learned (2)

Requirements

- The views helpful in a real life software development process?
- The views greatly depend on the traceability support system

Quality of the Documentation

- Validation possibilities improve the quality of the work products
- The descriptions in the documentation is more harmonized

Reconstruction Technology

- In order to get a high recall, we have to live with a rather low precision

Future Work

- Explore new (industrial) cases with different development approaches; different specification templates, design and test paradigms
- Reduce the effort to validate the reference traceability matrices using an incremental approach
- Define more views with more 'rich' information using feedback from industry
- Improve and expand ReqAnalyst tool suite

Questions

???

More info:

M.Lormans@ewi.tudelft.nl / Marco.Lormans@LogicaCMG.com

<http://www.st.ewi.tudelft.nl/~lormans>

ReqAnalyst Demo

[ReqAnalyst](#)

Coverage Views

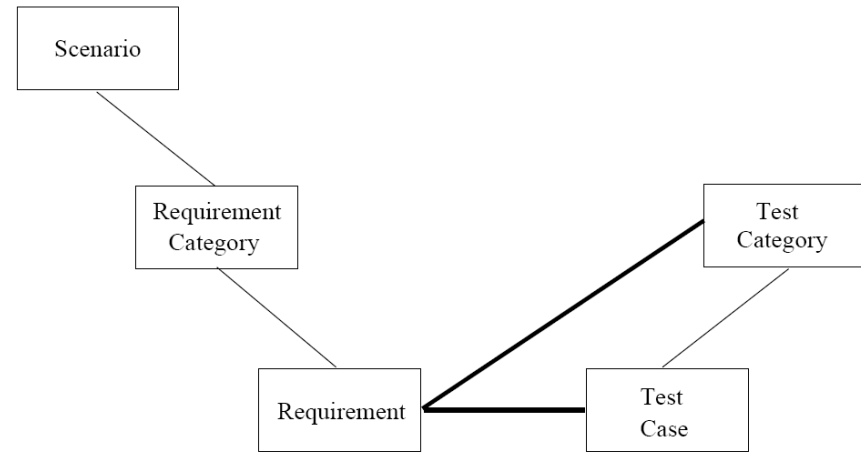
- Use reconstructed traceability to add status to particular requirements, e.g.:
 - Requirement is covered by design artefact
 - Requirement is covered by test case
- Coverage metric:

$$\text{cov}_{test} = \frac{|req_{test}|}{|req_{total}|}$$

Example

Scenario1 is:

- Covered by ReqCat1
- Covered by Req1, Req2 and Req3
- Req1 is covered by TestCat1
- Req2 is covered by TestCat1
- Req1 is covered by TestCase1
- TestCase1 not executed
- TestCase2 did not pass



Quantitative Assessment of Results

Recall: the percentage of correctly reconstructed links compared to the total set of correct links

$$recall_i = \frac{|correct_i \cap retrieved_i|}{|correct_i|}$$

Precision: the percentage of correctly reconstructed links compared to the total set of retrieved links

$$precision_i = \frac{|correct_i \cap retrieved_i|}{|retrieved_i|}$$

Discussion of Results

Quality of Reference Matrix

- ???

Reconstructions Settings

- ??

Reconstruction Quality

- ??

Case Configuration

Number of Requirements Categories	<u>43 artifacts</u>
Size of Requirements Categories	1168 terms
Average number of terms per document	183 terms
Number of Requirements	<u>121 artifacts</u>
Size of Requirements Documents	695 terms
Average number of terms per document	29 terms
Number of Test Categories	<u>29 artifacts</u>
Size of Test Categories	589 terms
Average number of terms per document	183 terms
Number of Test Cases	<u>98 artifacts</u>
Size of Test Cases	886 terms
Average number of terms per document	107 terms
Total number of indexed terms	1783 terms
Average number of terms per document	93 terms

Results of Requirements to Test Categories



Link Type	ϵ	Reconstructed Links		Missing Links	Recall	Precision	Validation Percentage	Coverage Percentage
		Correct Positives	False Positives					
Requirements to Test Categories	20%	53	31	57	0.48	0.63	2	43
	40%	76	329	34	0.69	0.19	12	62
	60%	83	728	27	0.75	0.10	23	68
	80%	83	747	27	0.75	0.10	24	68
$c = 0.2$	80%	95	1392	15	0.86	0.07	42	77
$c = 0.1$	80%	107	2159	3	0.97	0.05	65	83

The actual coverage currently is 85%